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A RETROSPECTIVE EVALUATION OF OXYGEN RECOMPRESSION  
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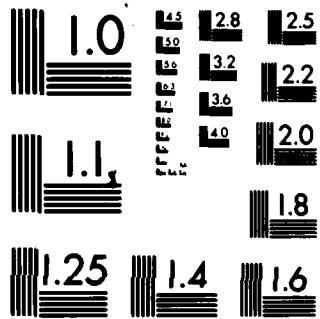
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# A RETROSPECTIVE EVALUATION OF OXYGEN RECOMPRESSION PROCEDURES WITHIN THE U.S. NAVY

C. G. GRAY

REPORT NO. 83-12

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PROCEDURES WITHIN THE U.S. NAVY

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Classification	Confidential
Control	None
Approved for Public Release Under the Freedom of Information Act	Yes
Auth. to Copy	None
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Report No. 83-12, supported by Naval Medical Research and Development Command, Bethesda, Maryland, Department of the Navy, under research Work Unit M009-PN.001-1157. The views presented in this paper are those of the author. No endorsement by the Department of the Navy has been given or should be inferred.

\*Environmental Physiology Department

I wish to express my thanks to CDR T. E. Berghage for the stimulation he provided to accomplish this analysis. His assistance throughout the process has proven invaluable in the production of this Report.

Recompression procedures for treatment of decompression sickness (DCS) and arterial gas embolism (AE) have undergone considerable evolution over the past 20 years. Medical improvements and oxygen tables were adopted in 1967 to improve treatment results and shorten treatment times, and in 1978 treatment table 4A was eliminated and additional restrictions on treatment length were provided. An evaluation of treatments conducted in U.S. Navy hyperbaric facilities has not been accomplished since 1970.

A retrospective survey was performed to assess overall usage of the treatment tables, therapeutic results, appropriateness of table selection, and adequacy of treatment when possible. Evaluations were based on published criteria existing in the U.S. Navy Diving Manual at the time the treatments were administered and on information contained in accident/injury reports for each treatment supplied by the Naval Safety Center.

Cases involving DCS and AE from 1971 to 1981 were reviewed. Treatment results were reported as complete relief (CR), substantial relief (SR), partial relief, or fatal, and follow-up treatments were classified as retreatments (R). From 1971 to 1978 there were 477 cases treated on oxygen tables with 33 R's and 3 fatalities yielding a 92.5% one-treatment success, and for 1979 to 1981 there were 274 cases with 9 R's and 4 fatalities yielding a 95.3% success. From 1971 to 1978, there were 386 cases with reported CR and 88 with SR. Of the 386 cases with CR, there were 14 R's (3.6%), whereas, of the 88 cases with SR, there were 19 R's (21.6%). There was a similar difference in retreatments between CR and SR cases for the 1979 to 1981 period and for results from individual treatment tables. Departures from published U.S. Navy standards for treatments for the 1971 to 1978 and 1979 to 1981 periods exceeded 10% and were not significantly different. These nonstandard uses of the recompression therapy tables prompted a 14% retreatment rate, which is significantly higher than the 5% retreatment rate for standard use of the tables. Use of the oxygen tables, according to U.S. Navy standards, produced a 95.5% overall one-treatment success. The term "substantial relief" introduces a possible ambiguity that promotes misinterpretation of treatment criteria and may disguise incomplete treatments.

## INTRODUCTION

Procedures for treatment of decompression sickness (DCS) and arterial gas embolism (AE) have undergone a considerable evolution since their inception. In spite of substantial research, the pathophysiology of DCS remains in question and much of the progress in recompression therapy has been based on empirical data. Adoption of minimal recompression procedures using oxygen (1,2,3) and the use of adjunctive therapy with recompression more recently have claimed improvements in treatment results (4,5). Previous surveys of treatments (6,7,8,9,10) have demonstrated the advantages of the oxygen treatment tables over most of the air treatment tables. These data and more recent reports (11,12,13,14) have emphasized that severity of symptoms and treatment delays are considered primary determinants affecting therapeutic success, although reported departures from established treatment criteria (13,15) could be responsible for some of the poor results observed. Refinements in treatment procedures may be partially negated by inadequate patient evaluation, incorrect diagnosis, inappropriate treatment table selection, improper delivery of the prescribed therapy, and confusion on criteria regarding endpoints of therapy.

Within the jurisdiction of the U.S. Navy, a firm and logical usage of existing treatment tables has been prescribed in the U.S. Navy Diving Manual (16). The treatment flow diagram contained in Chapter 8 used in conjunction with the recompression treatment tables is intended to provide adequate guidelines to treat most cases properly. However, the changes implemented during the last decade have not been adequately evaluated and an evaluation of treatments delivered by U.S. Navy facilities has not been completed since 1970. Recompression treatments have been recorded at the Naval Safety Center which include a computer tabulated questionnaire and a narrative summary (Fig. 1). This survey retrospectively reviews all treatments of DCS and AE reported from 1971 to 1981. The cases are separated according to the treatment table used with an assessment of therapeutic results, appropriateness of table selection, and adequacy of treatment when possible. This summary should provide some additional insight on the effectiveness of the published U.S. Navy standard treatment recommendations.

## METHODS

Diving ACCIDENT/INJURY Reports provided by the Naval Safety Center for DCS and AE cases occurring from 1971 to 1981 were reviewed. However, at least through 1978, many treatments were unrecorded. The cases were subdivided according to treatment table used, and the narrative descriptions provided with each case were evaluated and compared with the tabular data (Fig. 1, p. 4). The narrative, when adequate, provided a descriptive background of the incident, the treatment, and the results, with the results reported as "complete relief," "substantial relief," "partial relief," or "fatal." Based on the guidelines for treatment (16) at the time the treatments were delivered, and a clinical interpretation of the situations based on the narratives, the results of the treatments were assessed. These evaluations were based on the author's qualification and experience as a Navy qualified Diving Medical Officer. Where inadequate information for a judgment on the criteria for treatment, or where inadequate treatment results were provided, the cases were assumed to be appropriately treated with relief as indicated. A number of missed decompression cases were included, but poor narrative and tabular data prohibited adequate separation of asymptomatic from symptomatic cases. These cases may serve to elevate the treatment success rates. Cases attributable to non-DCS causes and undergoing full or partial treatments are not included. It was not possible in all cases to differentiate who was responsible

Figure 1 DIVING ACCIDENT/INJURY

## DIVING ACCIDENT/INJURY

DATE AND L.D.: 03/26/81 NO 073A

Purpose of Dive Lobster  
Activity Name USS TENDER

### Initial Accident

<u>Recurrence Number</u>	<u>Sign</u>	<u>MOST SIGNIFICANT Location</u>	<u>INITIAL Organ System</u>	<u>SIGN Intensity</u>	<u>Treatment Table</u>	<u>Relief Depth</u>	<u>Treatment Gas</u>	<u>Treatment Outcome</u>	<u>Sub Rel 1</u>
0	Muscular Weakness	Lower Body	QNS Motor	Severe	6 M	60	Other		

NARRATIVE

THIS 49 Y/O MALE RETIRED USN OFF. CIV. QUA. SCUBA DIV MADE 1 DIV to 116 FSW BT 16 MIN PLUS. WHEN PT SURFACED HE FELT SHARP PAIN IN BACK OF NECK. PT NEXT NOTICED A WOBBLY FEELING IN LEGS. PT REENTERED WATER FOR SELF TX. TIME 6 DEPTH, UNKNOWN. PT FELT HE WAS BETTER AND WENT HOME. PT AWOKE LATER THAT EVENING WITH A CRAMP-TYPE FEELING IN LEGS. PT BROUGHT TO THIS FACILITY FOR TX. PT EXAM AND TREATED ON TREATMENT BY DIV. PT RETREATED 2 DAYS LATER ON TT5. DIAG: DCS TYPE II CAUSE: UNDETERMINED. POSSIBLE OMITTED "T".

for the treatment decisions (Diving Medical Officer or Master Diver) and no summary was attempted. All patients were treated in Navy recompression facilities using U.S. Navy procedures.

The diving manual (16) has given authority to the Diving Medical Officer (DMO) to alter the recompression tables at his discretion. The treatment logic provided in the diving manual indicates that if "relief" is not achieved on a shorter table, then a longer table should be employed. TT-5 was adopted for a specific use (pain only symptoms, relieved within 10 minutes at 60 FSW). If those criteria are not met, then TT-6 or 6A are to be employed with extensions as necessary to achieve relief. Using this conservative treatment scheme as a basis for delineating standard from nonstandard use of the recompression therapy tables, for this analysis non-standard uses of the tables are: 1) Any modification or extension to TT-5; 2) Cases treated on TT-5 where the narrative indicates pain was relieved after 10 minutes at 60 FSW or cases with Type 2 symptoms; 3) Cases treated on TT-6 or TT-6A, with or without extensions that yielded incomplete relief and may have benefitted from further extensions; or 4) Nonstandard use of TT-5A between 1971 and 1977 or any use after 1977 (TT-5A was eliminated in 1976). All of these criteria for the selection of non-standard treatments resulted in shortening of the treatment schedules and are considered as non-standard regardless of the results. One-treatment success is derived by adding complete relief and substantial relief cases and subtracting retreatments and fatalities.

Change 2 to the U.S. Navy Diving Manual (16) was implemented in June 1978. This was intended to improve treatment results by clarifying the treatment criteria and decision processes. To assess the effectiveness of this change, the years 1979 to 1981 were evaluated separately to allow comparison with the 1971 to 1978 period. Additionally, for 1979 to 1981, the cases treated on TT-6 or TT-6EX were further subdivided into treatments administered for Type 1 (pain only) and Type 2 (serious symptoms) DCS to assess relative utilization and results for these types of cases.

The data for complete relief, substantial relief, fatalities, overall success, and non-standard treatments are expressed as a percent of the total number of cases (% of TOTAL). The cases are designated as complete relief or substantial relief as the outcome of the initial treatment, and the retreatment rate is expressed as a percentage of the group from which they came (% of Complete Relief or % of Substantial Relief).

For statistical comparisons it is assumed that the population from which diving injuries occur is no different for each treatment group. For this analysis a z-test for independent samples drawn from populations of equal proportions was used (17). The probability of a difference is stated for each sample comparison that fulfills the required criteria for sample size and composition.

#### RESULTS

Referring to Table 1 for 1971 to 1978, there was a total of 477 cases treated on the minimal recompression oxygen tables, with 33 retreatments and 3 fatalities. Of the cases experiencing complete relief, there was a 3.6% retreatment rate. The one-treatment success rate of the standard  $O_2$  treatments is significantly better than the success rate for the non-standard treatment cases ( $p < .001$ ). The success rate for the "air or other" treatments is not significantly different from the total of the  $O_2$  treatments, but the number is relatively small ( $n=47$ ). (See Table 1, page 6)

For the 1979 to 1981 one-treatment success for standard ( $n=247$ ) treatment cases (95.6%) is greater than for the non-standard ( $n=26$ ) treatment cases (92.6%), at a significance of  $p < .05$ .

Table 1  
Summary of Success from a Single Recompression Treatment

		Number of Cases		Complete Relief (%) of Total		Retreatments (% of Comp. Relief)		Substantial Relief (% of Total)		One-Treatment Success (% of Subst. Relief)		One-Treatment Fatal (Fatal)	
<b>1971-1978</b>													
$O_2$ Table Standard TX <sup>2</sup>	418	369	(88.3%)	13	(3.5%)	47	(11.2%)	10	(21.3%)	94.0%	2		
$O_2$ Table Nonstandard TX	59	17	(28.1%)	1	(5.9%)	41	(69.5%)	9	(22.0%)	81.4%	1		
Total $O_2$ TX	477	386	(80.9%)	14	(3.6%)	88	(18.5%)	19	(21.6%)	92.5%	3		
Air or Other TX	53	34	(72.3%)	3	(8.8%)	13	(27.7%)	0		93.6%	6		
<b>1979-1981</b>													
$O_2$ Table Standard TX	247	230	(93.1%)	5	(2.2%)	13	(5.3%)	2	(15.4%)	95.6%	4		
$O_2$ Table Nonstandard	26	4	(14.8%)	0		23	(85.2%)	2	(8.7%)	92.6%	-		
Total $O_2$ TX	274	234	(85.4%)	5	(2.1%)	36	(13.1%)	4	(11.1%)	95.3%	4		
Air or Other TX	8	8	(100%)	0	(0.0%)	-		-		100%	0		

<sup>1</sup>One-treatment success = Complete Relief + Substantial Relief - Retreatments - Fatal x 100  
<sup>2</sup>TX = Treatment

**FIGURE 2A**  
**SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT USING TABLE 5**

1971 - 1972

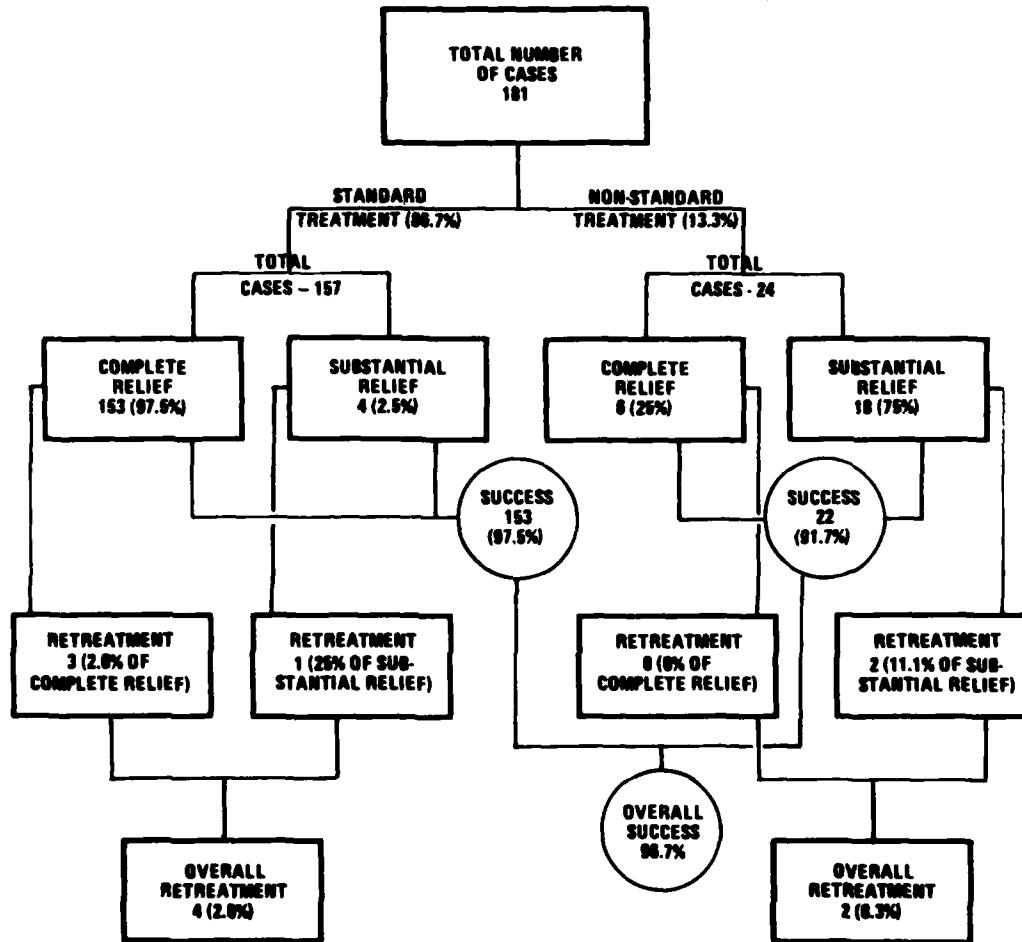
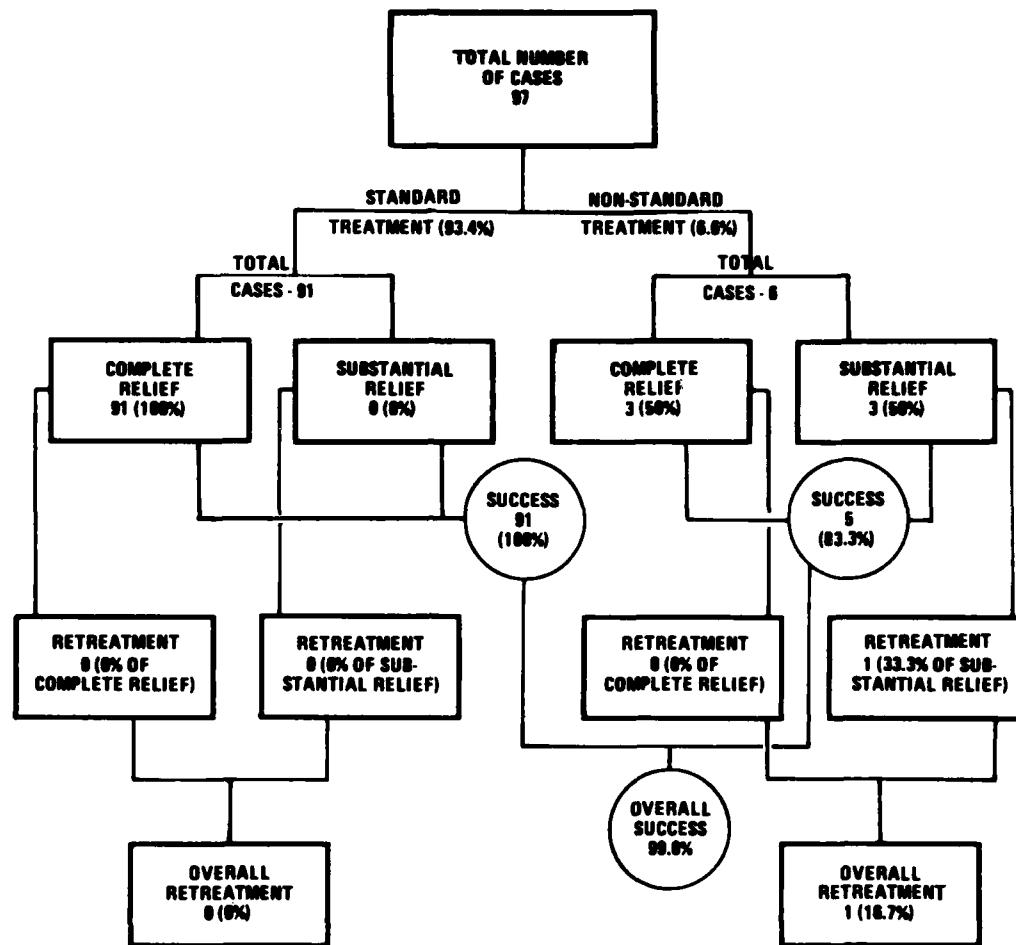


FIGURE 2B  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT USING TABLE 5  
1979 - 1981



The non-standard utilization of the treatment tables was 12.2% and 10% for the 1971 to 1978 and 1979 to 1981 periods respectively and were not significantly different. The one-treatment success when using non-standard treatment schedules was significantly ( $p < .01$ ) improved for the 1979 to 1981 period over the 1971 to 1978 period.

Success for a single recompression treatment using TT-5 is summarized in Figures 2A and 2B for the years 1971 to 1978 and 1979 to 1981 respectively. Referring to Figure 2A (see p. 7), there was a total of 181 cases treated on TT-5 for the 1971-78 period. Of those cases, 157 were treated according to standard treatment criteria and 24 cases used TT-5 when the standard treatment criteria were not met (Pain only DCS, relieved within 10 min. at 60 FSW). Of the 157 standard treatment cases, there were 4 retreatments yielding a 97.5% one-treatment success (153/157). Of the 24 non-standard, there were 2 retreatments yielding only a 91.7% one-treatment

success (22/24). The overall retreatment rate for non-standard treatment cases (8.3%) is more than 3 times the standard treatment retreatment rate (2.6%). Additionally, adding the "Complete Relief" cases for both standard and non-standard treatments yields 159 cases and adding the "Substantial Relief" cases yields 22 cases. Adding the "Retreatments" following "Complete Relief" therapy yields 3 cases, and adding "Substantial Relief" "Retreatments" yields 3 cases. Thus the retreatment rate for "Substantial Relief" cases (13.6%) is more than 6 times the "Complete Relief" retreatment rate (2.0%). Referring to Figure 2B, the incidence of non-standard treatments using TT-5 during the 1979 to 1981 period (6.6%) is lower than for the 1971 to 1978 period (13.3%). There is a marked improvement in treatment success for the 1979-1981 period for unknown reasons possibly related to the effects of other changes, such as adjunctive therapies and decreased treatment delays, which could not be evaluated.

Figure 3 presents the summarized data for the usage of TT-5A from 1971 to 1978. It illustrates that standard use of the table yields good success (100%). However, 23.8% (5 cases) of the total were not administered according to established criteria. These non-standard treatment cases had a substantially higher (40%) retreatment rate than standard treatment cases (0%). Although the number is small, this suggests that when appropriately used, TT-5A was an effective table. There were no recorded uses of TT-5A after 1978. (See Fig. 3, p. 10)

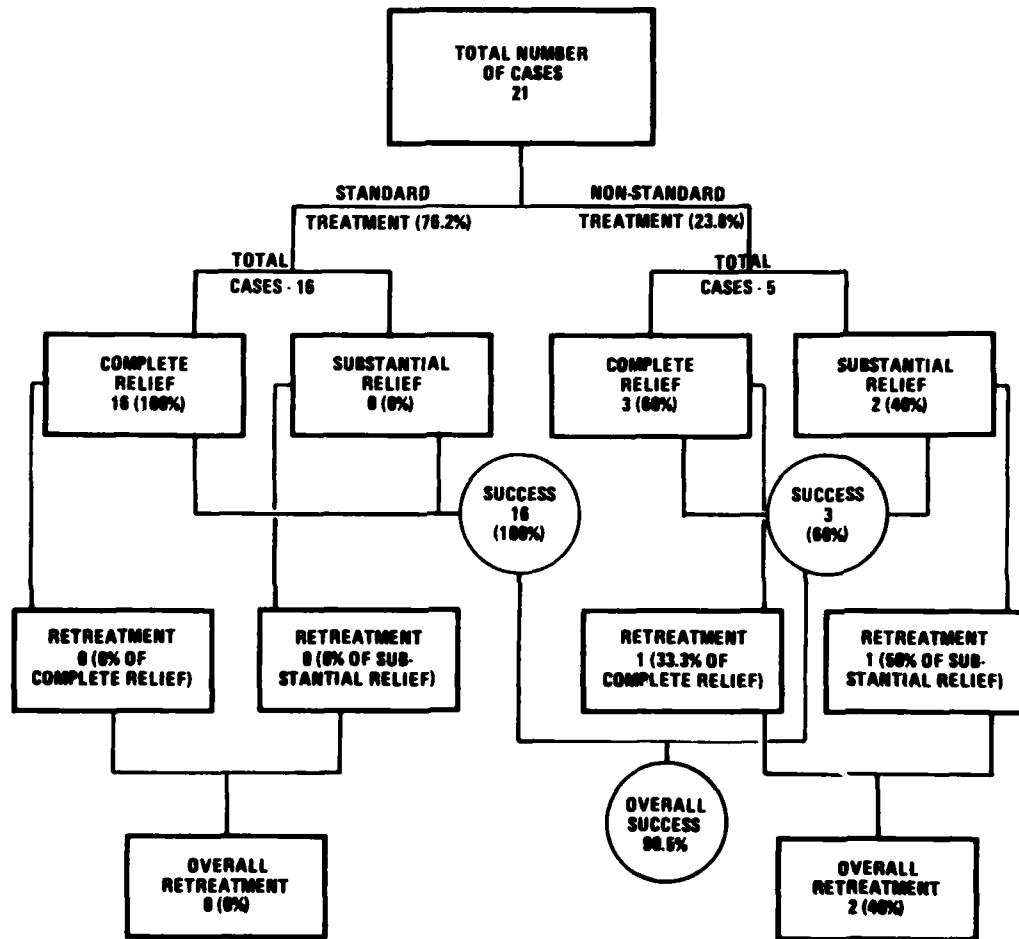
Modifications to treatment table 5 (TT-5EX) are at variance with established criteria. All such modifications, including experimental changes (considered non-standard for this analysis) are shown in Figure 4 with 13 cases for the 1971 to 1981 period. Although the complete relief category retreatment rate was zero, the overall retreatment rate of 23.0% is approximately 7 times greater than experienced with either TT-5 or TT-6. (See Figures 4 and 5, pp. 11, 12)

The use of TT-6 for 1971 to 1978 is shown in Figure 5. Treatments administered in accordance with standard guidelines yielded a 97.8% one-treatment success. The non-standard usage of TT-6 produced a retreatment rate 12 times greater (25%) than the standard use of the table (2.2%). The retreatment rate of 11.1% for the combined substantial relief categories is substantially greater than for the combined complete relief categories (2.4%).

Table 2 (see p. 13) summarized the subdivided results for the use of TT-6 from 1979 to 1981 for a single recompression. TT-6 was used to treat Type 2 (serious symptoms) complaints (n=57) twice as frequently as for Type 1 (pain only) complaints (n=27). The overall retreatment rates for Type 1 and Type 2 cases for 1979 to 1981 are not significantly different from the retreatment rate for the 1971 to 1978 standard treatment cases or from each other.

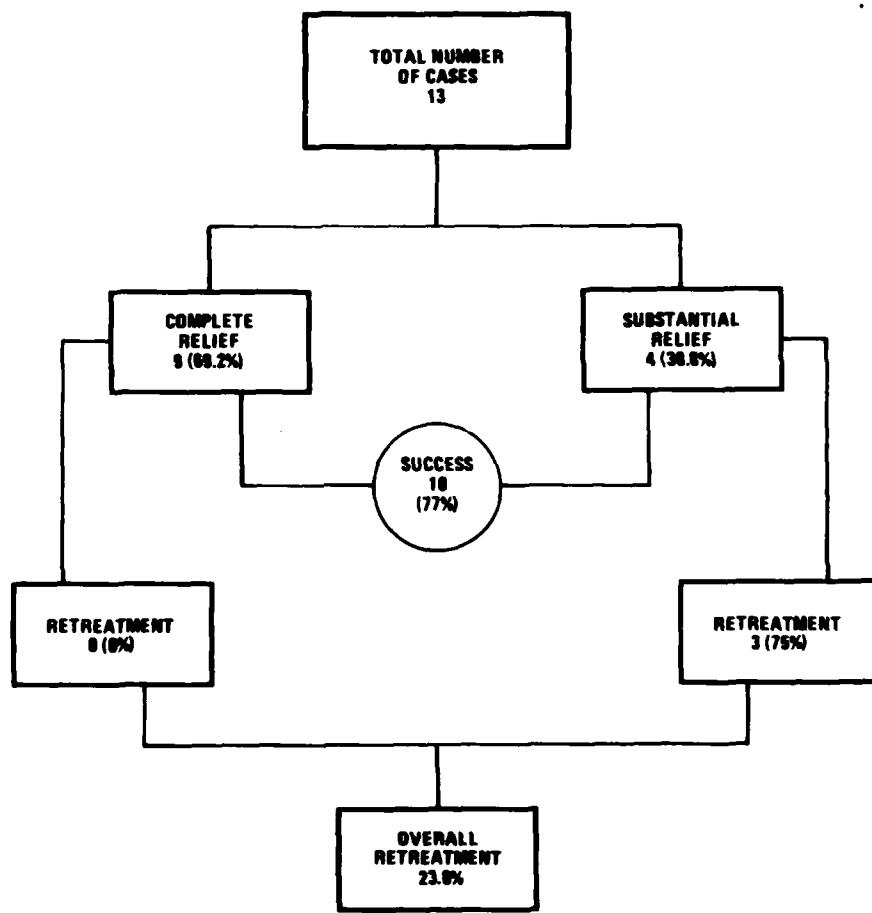
Figures 6A and 6B (see pp. 14,15) recount the use of TT-6A or TT-6A extended for the 1971 to 1978 and 1979 to 1981 periods respectively. From 1971 to 1978 for these difficult and serious cases, there was a 91.7% one-treatment success when used according to the standard guidelines, whereas non-standard usage produced only a 77.8% one-treatment success (4 times greater retreatment rate). There is an improving trend for the 1979 to 1981 period with no retreatments in the non-standard category. For the 1971 to 1978 period, the retreatment rate for the combined substantial relief categories (18.7%) is more than 5 times greater than for the combined complete relief categories (3.7%). This may not be surprising if the "substantial relief" category is intended to imply that retreatments may follow as needed.

FIGURE 3  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT USING TABLE 5A  
1971 - 1978\*



\* There were no cases treated on T-5A for the 1979-1981 period.

FIGURE 4  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT USING TABLE 5 EX\*  
1971 - 1981



\* EX = Extensions of treatment table used. This is a nonstandard use of the treatment tables and all uses are considered non-standard regardless of results.

FIGURE 5  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT USING TABLE 6  
1971 - 1978

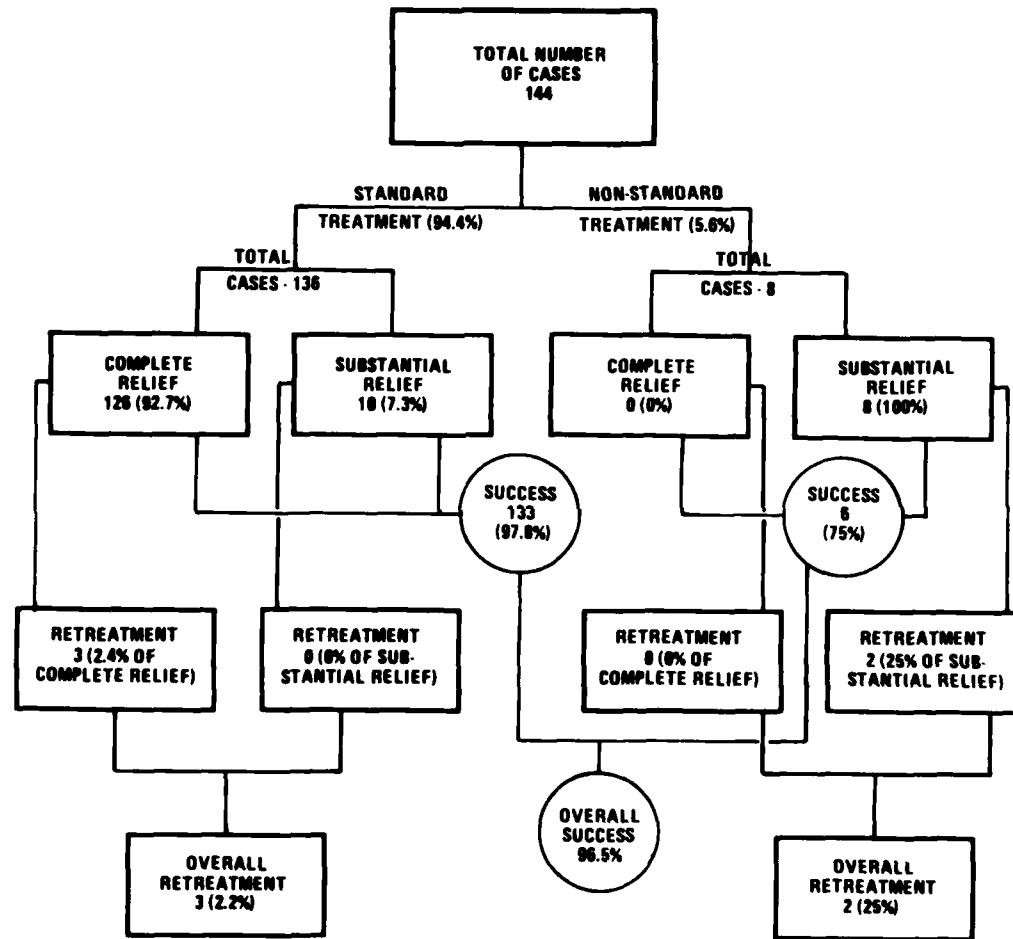


Table 2  
Success for a Single Recompression Treatment Using Table 6  
from 1979 to 1981

Cases**	Complete Relief (% of Total)	Retreatments (% of Comp. Relief)	Substantial* (% of Total)	Overall Retreatments (% of Total)
Type 1: 32	27 (84.4%)	1 (3.7%)	5 (15.6%)	3.1%
Type 2: 57	54 (94.7%)	1 (1.9%)	3 (5.3%)	1.8%
Total: 89***	81 (91.0%)	2 (2.5%)	8 (9.0%)	2.5%

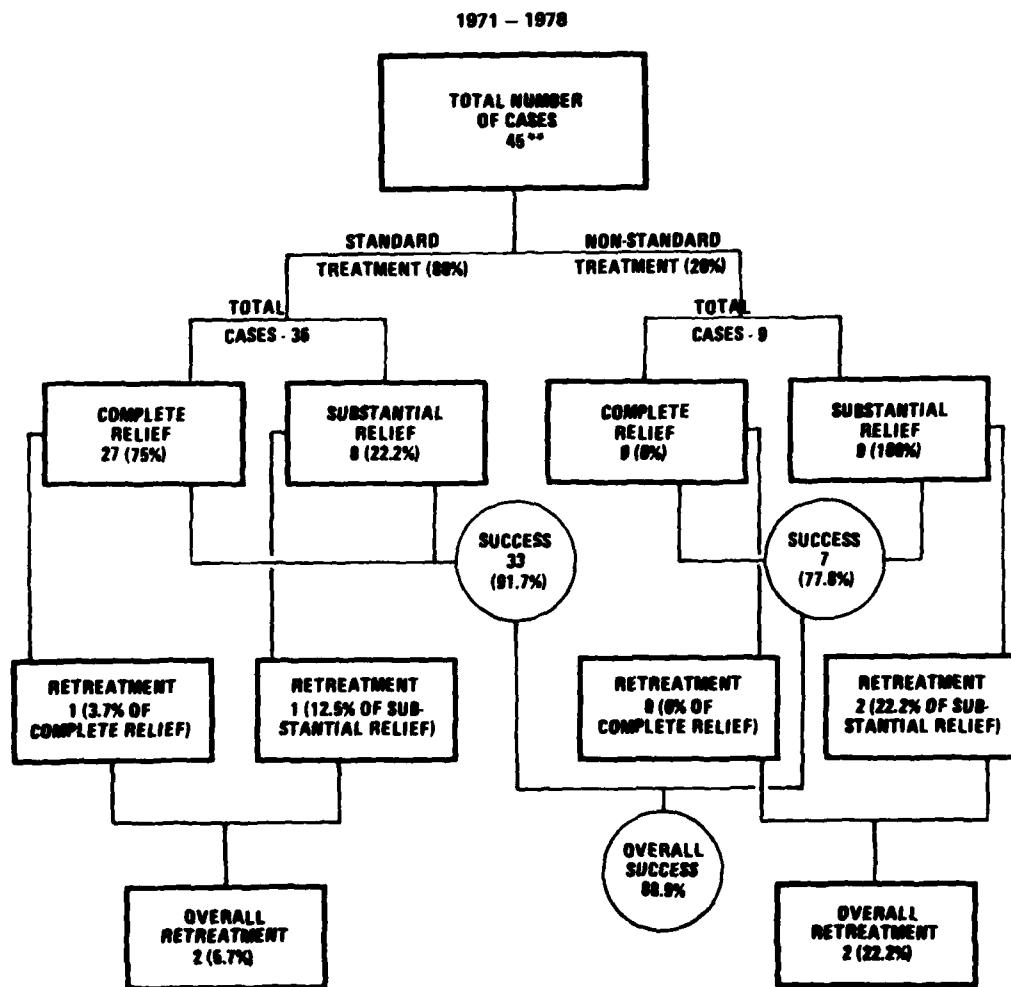
\* No retreatments within this subdivision  
\*\* For this period there were 8 cases of apparent incomplete treatment and no retreatments  
\*\*\* Nonstandard treatment incidence = 9.0% (8/89)

Table 3  
Success for a Single Recompression Treatment Using  
Table 6 Extended 1979 to 1981

Cases *	Complete Relief (% of Total)	Retreatments (% of Comp. Rel.)	Substantial or Partial Relief (% of Total)	Retreatments (% of Sub.Rel.)	Overall Retreatments (% of Total)
Type 1: 10	6 (60.0%)	1 (16.7%)	4 (40.0%)	0 (0.0%)	10%
Type 2: 35**	20 (57.1%)	1 (5.0%)	14 (40.0%)	2 (14.3%)	8.6%
Total: 45***	26 (57.8%)	2 (7.7%)	18 (40.0%)	2 (11.1%)	8.9%

\* For this period there were 7 cases of apparent incomplete treatment and no retreatments within those cases.  
\*\* Includes 1 fatality  
\*\*\* Non-standard treatment incidence = 15.9% (7/44)

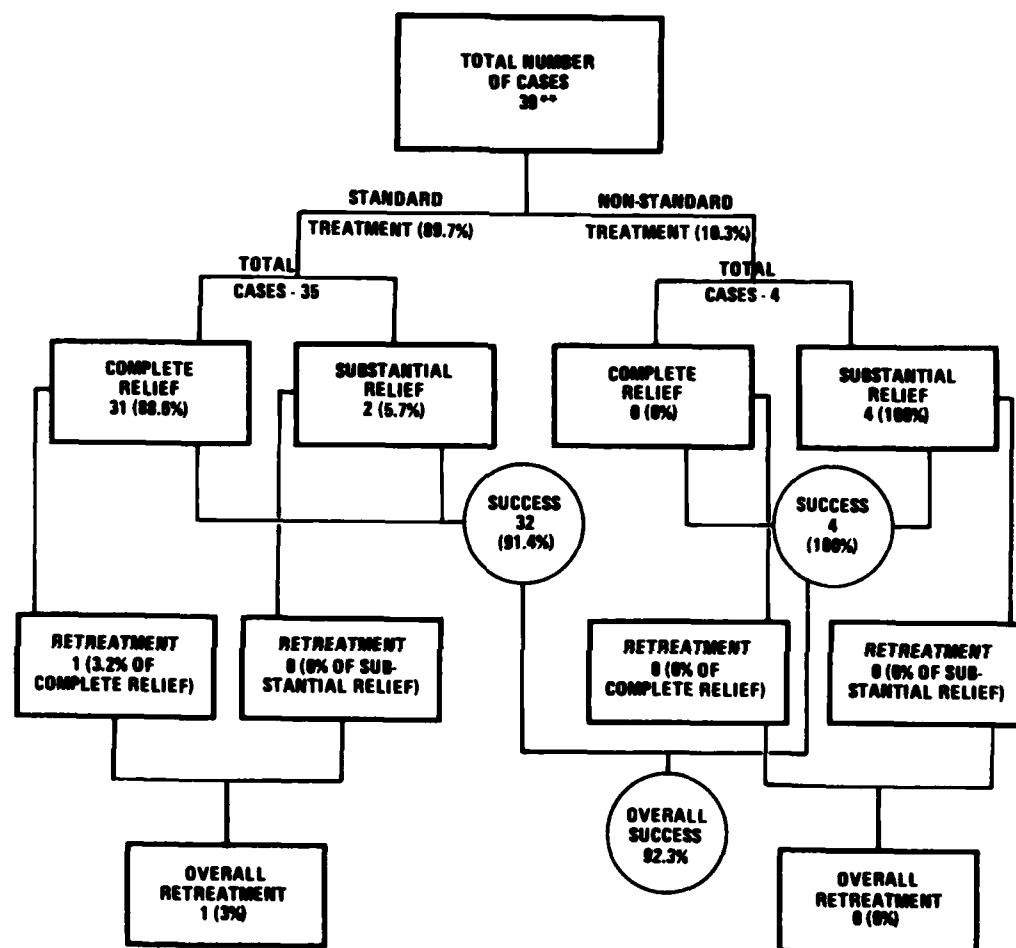
FIGURE 6A  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT  
USING TABLE 6A OR TABLE 6A EX\*



\* EX = Extensions of treatment table used  
\*\* Includes 1 fatality.

FIGURE 6B  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT  
USING TABLE 6A OR TABLE 6A EX\*

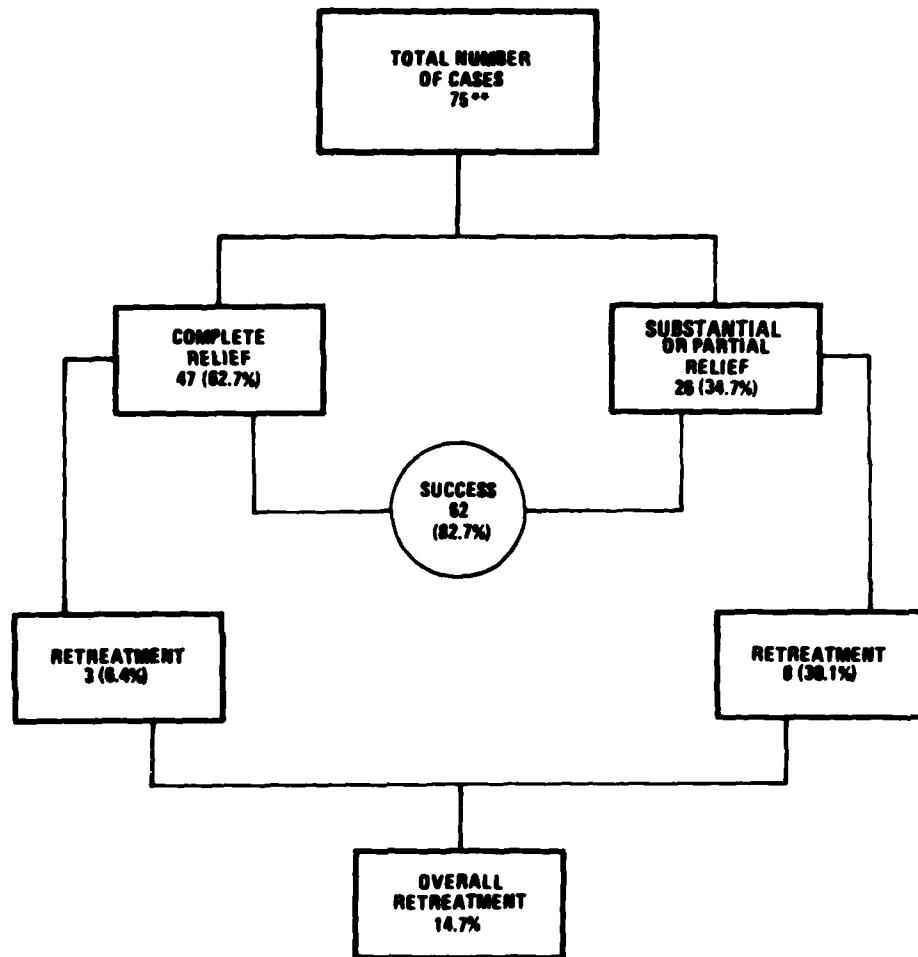
1979 - 1981



\* EX = Extensions of treatment table used.  
\*\* Includes 2 fatalities.

Cases treated on a TT-6EX with additional  $O_2$  breathing periods at 60 FSW or 30 FSW, or returned from 30 FSW to 60 FSW after a recurrence of symptoms are illustrated in Figure 7 and Table 3 for the 1971 to 1978 and the 1979 to 1981 periods respectively. These cases constitute more

FIGURE 7  
SUCCESS FOR A SINGLE RECOMPRESSION TREATMENT USING TABLE 6 EX\*  
1971 - 1978



\* EX = Extensions of treatment table used.

\*\* Includes 2 fatalities.

difficult treatment decisions and are more difficult to critically evaluate. However, of the combined 120 cases for 1971 to 1981 there were 8 cases (6.7%) that were improving but unresolved when decompression began or continued. These cases were not extended to the authorized limit (without medical officer recommendation) provided in the Diving Manual (16). Although the retreatment rates are significantly higher than for other tables, the serious nature of these cases does not

Table 4  
Success for a Single Recompression Treatment Using  
Air or Saturation Treatments

1971 to 1981					
Treatment Table Used	Number of Cases	Complete Relief	Retreatments	Substantial Relief	Retreatments
1, 1A	10	10	0	0	0
3	6	3	2	3	0
4, 4EX	16*	4	0	7	0
Saturation**	24	22	1	2	0
Other	5***	3	0	1	0
Total****	61	42	3	13	0

\* Includes 5 fatalities  
\*\* Cases occurred during saturation dives, treated with saturation procedures  
\*\*\* Includes one fatal case  
\*\*\*\* Overall retreatment rate 4.9%.

Table 5  
Success Following Recompression Retreatments

1971 to 1981			
Follow-up Treatment Table Used	Number of Cases	Complete Relief	Substantial Relief
5,5A, 5EX	4	-	4
4,4EX	4	2	2
6,6EX	29*	17	11
6A	1	-	1
Saturation	1	1	-
Other	2	-	2

\* Includes one Fatal case.

allow appropriate comparisons. Combining the TT-6EX totals for 1971 to 1981 yields 73 cases with complete relief and 44 cases with substantial or partial relief. Of those cases, the retreatment rates of 6.8% and 22.7% respectively are markedly different, but the significance for these serious cases is uncertain and may relate to intentions to retreat as necessary.

All other recompression treatments occurring during saturation dives or those using air tables are listed in Table 4. Table 5 provides the results of retreatments listed according to the table used for the repeat treatment. These cases are included for completeness with no conclusions drawn from these small numbers.

#### DISCUSSION

The data presented herein suffers from several weaknesses. It is a retrospective secondary evaluation, all conditions are not known, cases with insufficient data could not be fully scrutinized, some semantic problems are evident, and the evaluations are based on one medical officer's interpretation. Additionally, asymptomatic cases, included under the "missed decompression" category of causes are incorporated in the treatment results. There were also a significant number of seemingly partially treated cases that were lost to follow-up and may have benefitted from extended or repeated treatments. These cases could not be included, but would probably have elevated the retreatment rates for TT-6 or longer tables in the substantial relief category. Diving Manual (16) criteria for treatments are disputed by some, but they are defined as standard for this evaluation. Many cases prior to 1978 were not recorded at the Naval Safety Center and some of the selected subgroups for this analysis are relatively small samples. Accepting these shortcomings, the data provides some interesting information.

The U.S. Navy Diving Manual (16) presents a well-constructed treatment criteria and treatment logic system in Volume 1, Chapter 8. Delivery of non-standard treatments may generally not be from lack of evaluation, although inadequate evaluation by diving corpsmen and medical officers is considered a significant problem by some knowledgeable diving medical officers. The criteria for this review required that adequate information was presented to allow judgment of the appropriateness of treatment. This means that some evaluation was performed, but generally in these selected nonstandard cases, treatment criteria provided in the U.S. Navy Diving Manual (16) were apparently either misunderstood or disregarded. Some of these non-standard treatments probably represented real or perceived difficult cases that needed an alteration in the standard tables, or a well rationalized decision of the individual delivering the treatment. But, for whatever reason these abbreviated treatments were administered, the overall results indicate that their one-treatment success rates were significantly lower than for standard treatments. For the 1979 to 1981 period, there may be a better understanding of treatment rationale revealed in improvements in the results of non-standard treatments, but improvements in treatment delays and usage of adjunctive therapy may have contributed to this improvement. However, there remain many cases that are apparently undertreated due to misunderstandings of treatment logic or treatment endpoints.

From this evaluation, the term "substantial relief" apparently means different things to different people, ranging from only minor musculoskeletal soreness following a pain only treatment to a significant neurological deficit in a serious case. This semantic vagary may provide a haven for treatment short-cuts or incomplete evaluations. Although "substantial relief" with an intention to administer follow-up recompression treatments may be an acceptable result for treatment tables 6A-EX and 6-EX, or even 6 and 6A (with extenuating circumstances), this should not be an

acceptable logic for use of TT-5. It is not possible from this evaluation to separate the cases in which the treating authority selected abbreviated treatment schedules based on full knowledge of the compromise employed, from those who misunderstood or incompletely evaluated the situation. There were many cases where the term "substantial relief" was apparently used to describe "relief" as stated in the Diving Manual. In many cases the use of "substantial relief" was considered to be equivalent to the implied, but not stated, "complete relief" criteria used in the Diving Manual. This semantic ambiguity was apparently the basis for misunderstanding the appropriate endpoint for treatment tables (and extensions). This is particularly significant in the substantially higher retreatment rate for TT-5 in those cases with reported "substantial relief."

This problem may be avoided if the term "substantial relief" is prohibited in report phraseology. Any result other than "complete relief" should be specified as partial relief, with specific deficits (i.e., residual soreness; two-point discrimination 2 inches; deficit cold sensation; paresthesia; 3+ strength in a specific muscle group, etc.) identified as a percentage of normal or a zero to 5+ grading scale. This change in reporting format may prompt more complete evaluations and reduce incomplete therapies. This should serve to improve the one-treatment results.

The incidence of non-standard treatments was no different for the 1979 to 1981 period than for the 1971 to 1978 period although there was improved success for the 1979-1981 period. It is evident from these results that publication of guidelines and criteria does not completely eliminate problems in treatment inadequacies. Some yearly update of treatment selection procedures for all responsible personnel may be considered via self-administered course, test, or other means. People responsible for the medical evaluations may additionally have periodic updates in diagnostic procedures; i.e., differentiation of pain syndromes and neurologic exams and their interpretation.

Bayne (11) has demonstrated that prompt aggressive treatment provides a 100% success rate. With delays in treatment and physiologic variability we may be willing to accept a 1 to 5% retreatment rate, but should we accept a 10% divergence from standards in treatment delivery with decreased success rates or increased retreatment rates for initially undertreated cases? Minimal recompression tables provide excellent results, with an overall success of 95.5% for one treatment, when used according to published standards and exhibit an improvement over most of the air tables, with a reported overall success of 88% (6). Removal of ambiguity in result reporting and periodic educational updates seem to be the next step in improving treatment results.

#### SUMMARY

1. Use of the minimal recompression oxygen tables according to published criteria produces a 95.5% overall positive one-treatment success. This provides an advantage over the standard air treatment tables in a better success rate and shorter treatment times.
2. The incidence of recompression therapy departing from the USN Diving Manual standards exceeds 10% and these cases exhibit a substantially greater retreatment rate than cases treated on standard tables.
3. The descriptive term "substantial relief" is ambiguous, apparently promotes misinterpretation of the logical treatment scheme, and should not be used to describe treatment results.

4. There is a general retreatment rate of 1 to 3% even with properly treated cases (probably due to delays and physiological variability).
5. The retreatment rate for the cases resulting in "substantial relief" is significantly higher than those cases resulting in "complete relief" indicating that incomplete treatments may be disguised within this treatment outcome classification (particularly for TT-5).
6. Based on the data presented here, the only significant improvement in treatment results since the changes to the U.S. Navy Diving Manual in 1978 is an improvement in non-standard (cases treated with less than recommended recompression schedules) treatment results. The incidence of non-standard treatments has remained unchanged.

#### References

1. Bornman, P.C. Experience with minimal recompression, oxygen breathing treatment of decompression sickness and air embolism. U.S. Navy Experimental Diving Unit, Memorandum Report, 10 Feb. 1967.
2. Goodman, M.W. Decompression sickness treated with compression to 2-6 atmospheres absolute. Aerospace Medicine, 1964, 35(12):1204-1212.
3. Goodman, M.W. & Workman, R.D. Minimal-recompression, oxygen-breathing approach to treatment of decompression sickness in divers and aviators. U.S. Navy Experimental Diving Unit Report 6-65, November 1965.
4. Broussolle, Dr. Drugs for the treatment of decompression sickness. In: Mines and Safety Health Commission Congress on Medical Aspects of Diving Accidents, 1978, pp. 77-94.
5. Kindwall, E.P. Role of adjunctive drug and fluid therapy. In: Treatment of Serious Decompression Sickness & Arterial Gas Embolism, UMS Pub. No. 34 WS (SDS) 11-30-79.
6. Rivera, J.C. Decompression sickness among divers: An analysis of 935 cases. NEDU Report 1-63, February 1963.
7. Doll, R.E. & Berghage, T.E. Interrelationships of several parameters of decompression sickness. NEDU Report 7-65, 1 March 1967.
8. Kelly, J.S., Berghage, T.E. & Summitt, J.K. Review of Diving Accident Reports 1967. NEDU Report 10-68, 1968.
9. Summitt, J.K. & Berghage, T.E. Review of Diving Accident Reports 1968. NEDU Report 11-70, December 1970.
10. Summitt, J.K. & Berghage, T.E. Review of Diving Accident Reports 1969. NEDU Report 12-70, December 1970.
11. Bayne, C.G. Acute decompression sickness: A curable disease. JACEP 7:351-354, October, 1978.
12. Davis, J.C., Sheffield, P.J., Schuknecht, L., et al. Altitude decompression sickness: Hyperbaric therapy results in 145 cases. Aviation and Environmental Medicine, 1977, 48(8): 722-730.
13. Davis, J.C. Treatment of decompression accidents among sport Scuba divers with delay between onset and compression. In: Treatment of Serious Decompression Sickness and Arterial Gas Embolism, UMS Pub. No. 34 WS (SDS) 11-30-79.
14. Pelosi, G., Proietti, R., Dellamorte, F., et al. Decompression sickness: A medical emergency. Resuscitation (Netherlands), 1981, 9(3):201-209.

15. Leitch, D.R. Treatment of air decompression illness in the Royal Navy. In: Treatment of Serious Decompression Sickness and Arterial Gas Embolism, UMS Pub. No. 34 WS (SDS) 11-30-79.
16. U.S. Navy Diving Manual. Volume 1, (NAVSEA 0994-LP-001-9010), Change 2, 1978.
17. Mendenhall, W. Introduction to Linear Models and the Design and Analysis of Experiments. Belmont, CA: Wadsworth Publishing Co., 1968.

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20. Abstract (cont-i-ued)

A retrospective survey was performed to assess overall usage of the treatment tables, therapeutic results, appropriateness of table selection, and adequacy of treatment when possible. Evaluations were based on published criteria existing in the U.S. Navy Diving Manual at the time the treatments were administered and on information contained in accident/injury reports for each treatment supplied by the Naval Safety Center.

Cases involving DCS and AE from 1971 to 1981 were reviewed. Treatment results were reported as complete relief (CR), substantial relief (SR), partial relief, or fatal, and follow-up treatments were classified as retreatments (R). From 1971 to 1978 there were 477 cases treated on oxygen tables with 33 R's and 3 fatalities yielding a 92.5% one-treatment success, and for 1979 to 1981 there were 274 cases with 9 R's and 4 fatalities yielding a 95.3% success. From 1971 to 1978, there were 386 cases with reported CR and 88 with SR. Of the 386 cases with CR, there were 14 R's (3.6%), whereas, of the 88 cases with SR, there were 19 R's (21.6%). There was a similar difference in retreatments between CR and SR cases for the 1979 to 1981 period and for results from individual treatment tables. Departures from published U.S. Navy standards for treatments for the 1971 to 1978 and 1979 to 1981 periods exceeded 10% and were not significantly different. These nonstandard uses of the recompression therapy tables prompted a 14% retreatment rate, which is significantly higher than the 5% retreatment rate for standard use of the tables. Use of the oxygen tables, according to U.S. Navy standards, produced a 95.5% overall one-treatment success. The term "substantial relief" introduces a possible ambiguity that promotes misinterpretation of treatment criteria and may disguise incomplete treatments.

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